Folia Forestalia Polonica, series A, 2014, Vol. 56 (2), 105–112

ORIGINAL ARTICLE

DOI: 10.2478/ffp-2014-0010

Application of network analysis for development and promotion of sustainable tourism in public forests

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Abstract

The issue of sustainable tourism within valuable natural areas has been extensively discussed ever since the emergence of sustainable development philosophy in the 1990s. In view of growing public interest in nature recreation and tourism development, the importance of addressing this subject matter has hitherto increased significantly. The main objective of the present paper was to offer a tool for supporting development and promotion of sustainable tourism in Poland's forests managed by the State Forests – National Forest Holding. GIS technology, and specific tools for network analysis were used in the project. During task realization, only free and open software sources were used. The work was performed based on the example of the Forest District Żołędowo (Regional Directorate of State Forests in Toruń, Poland) with the use of District's spatial data resources. A web application was created to present information about tourist attractions and infrastructure on an interactive map with tools for route planning. As a result, there has been developed the web mapping application which provides general access to tourism related information and enables planning touristic routes by pre-specified criteria. Implemented routing algorithms can help traffic management and further protection of the areas vulnerable to anthropogenic pressures. The system created not only promotes attractive tourist sites but also, supports targeting tourist traffic, and accordingly – adds to the progress of sustainable tourism.

Key words

network analysis, tourism, geographic information system (GIS), geoportal, open source software

Introduction

Today, tourism is one of the largest and prospective industries in the world (Bhuiyana et al. 2010). An attractive landscape or particular elements of natural environment can offer the context for cultural attractions. In forest and wilderness areas, the attraction of isolation and solitude paradoxically appeals to many visitors (Hall 1998). The aesthetic or spiritual values of nature may be argument enough for its sustainable utilization (Pullin 2002). On the other hand, while tourism can contribute in a positive manner to socio-economic development and environmental protection, uncontrolled tourism growth can cause environmental degradation

Received 18 March 2014 / Accepted 17 April 2014

and destruction of fragile ecosystems. Thus, tourism should balance between human needs and environmental resources (Batyk et al. 2010). Tourism in Poland encompasses all kinds of the areas within reach in differentiated regions. After all, each territory has unique natural and cultural values that distinguish them from other spots on Polish or else European travel map.

Forest undeniably constitutes very attractive environment but it is vulnerable to human pressures. Any sightseer choosing forest for touristic purposes knows about its advantages in terms of climate, health or aesthetic beauty, however this knowledge must be supplemented by the rules on appropriate use of visited areas (Ważyński 1997; Zając et al. 2006). In Poland, the estimated number of people who visit forest tourist trails (for hiking, biking and horseback riding) is approximately 16.5 million annually. This includes 11 million people visiting National Parks and 5.5 million visitors in public forests administered by the State Forests – National Forest Holding (Zając 2006). Nevertheless, it is clear that too many visitors can bring about imbalance in forest environment. Improper tourism manifested by excessive recreation is a stress factor impacting upon forests (Arnberger and Eder 2012). One more problem is overcrowding, which mainly affects forests in vicinity of urban areas (Cieszewska et al. 2010). Kaczmarek (2011) argues that the value of forest sightseeing can be increased relatively easily through its thoughtful management of tourism, especially that focused on natural environment. In Poland's forests, considerable funds are invested in the development of tourism infrastructure. There are created educational trails, routes for walking and cycling, bridleways, camp sites, forest car parks and rest areas. Information boards are regularly located close to such places in order to notify about the codes of conduct in forest areas and provide information about natural environment around.

At the present time, websites have become the main source of information on tourist and recreation goals (Dion and Woodside 2010). Each forest district in Poland has its own website and spatial data, but there are no maps which could help to plan a tourist route. In the age of the Internet, such an application should be in the form of widely available service based on an interactive map. These days the main source of tourism related information can be found in all kinds of geoportals available at the Internet. This paper proposes the solution that takes advantage of GIS open source software and tools for network analysis. The designed geoportal presents tourism related information and allows planning various sightseeing routes at the same time as preserving environmentally valuable areas managed by the State Forests. The aim of this study was to use line vector data stored in digital forestry map along with other available spatial data to create a reliable and easy to use source of tourist information.

Methods

Network representation

The network is a system of interconnected linear features through which resources are transported or communication is achieved. A network model can be defined as a line graph, which is composed of links representing linear channels of flow and nodes representing their connections (Lupien et al. 1987). In other words, the network takes form of edges (or arcs) which connects pairs of nodes. The nodes can be junctions and edges or segments of a road. For the network to function as a real-world model, an edge has to be associated with a direction as well as with a measure of impedance which determine the resistance or travel cost along the network (Chiou et al. 2010).

Current models based on geographic information system (GIS) data typically represent the network as a collection of edges with nodes created at edge intersections. All that is needed to implement the resistance factors in attribute tables for the edges or nodes. Directions are an explicit part of vector network topology. If the directions are derived from digitising, a road map or ready coded network are received and form data supplier, however they may not correspond with real-world directions and need to be checked. Consequently, representation of network elements requires substantial amount of time to be devoted to data preparation and validation. This can be quite complex, depending on the amount of travel cost information to incorporate into the model: road width, speed limit, road class, delays at traffic lights and delays in taking turns at crossroads (Husdal 1999). Both geographic information systems (GIS) and network analysis are growing fields, with rapid methodological and scientific achievements observed

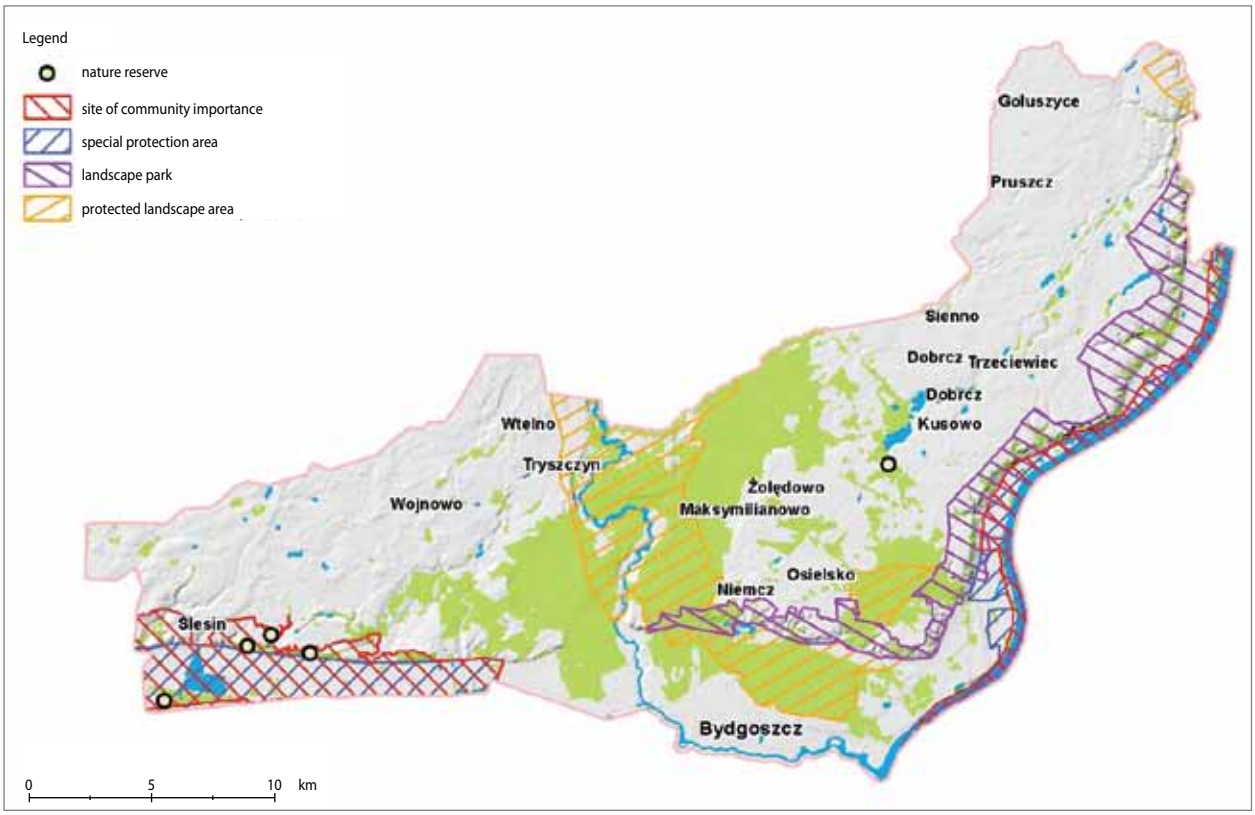

Figure 1. Location of legal forms of nature protection in the Forest District Żołędowo

in recent years. Currently implemented network analysis tools are dominated by routing functions. Routing is the act of selecting a course of travel and it is possibly the most fundamental logistical operation in network analysis. Without question, the most common objective in routing across networks is to minimize the cost of a route (Curtin 2007). The cost can be defined and measured in many ways, but it is commonly assumed to be a function of distance, time or impedance in crossing the network. Routing problems are conceptually simple, but mathematically complex and challenging. They have an underlying combinatorial structure (Fisher 2004). All the aforementioned aspects were included in project realization.

Study area

Application of network analysis was presented on the example of the Forest District Żołędowo, the Regional Directorate of the State Forests in Toruń, Poland (site location 53°13'30.34" N and 18°0'45.86" E). The District is situated close to Bydgoszcz city, where there live about 364,000 residents (Statistical Yearbook of the Republic of Poland 2012). More than 2500 hectares of forests are located within the administrative boundaries of the city, hence the area constitutes a popular natural area for recreation, walking and sports.

The Forest District Żołędowo manages an area of 12,039.59 ha including 11,717.36 ha of forest cover. Forest stands (on average 69-year-old) are dominated by coniferous habitats (90%) with the Scots pine prevailing. The Forest District comprises many forms of legal nature protection (fig. 1). Taking into consideration unique localization of the District and tourist needs and expectations, the study area has potential to attract great attention of people looking for a place where they can relax and take a rest.

Foundation of application

The application designed was to allow the user to access information important from the perspective of the sightseer, such as location and characteristics of touristic attractions, tourism infrastructure (forest education

trails, routes for walking and cycling, car parks, rest areas, hotels, restaurants, etc.) and route accessibility conditional on transportation means (e.g. motorcar, bicycle, by foot). It was taken into account that a route planner should include the following abilities:

- to indicate the start and end points of a route (starting point may be the end point),
- to choose on the map the waypoints selected to visit during the tour,
- to search location by place names,
- to demonstrate the tract achievable from the starting point when trip time or distance to cover are constrained,
- to contrast features of different routes (distance, time, elevation profile),
- to search routes depending on transport types,
- to enable printing of the route planned,
- to export the route to a file for later upload to a navigation application.

It was decided to use free and open source software in this study. Preparation of spatial data required several processing operations. The most important stage was to prepare network data properly. In the present study the following spatial data sources were used:

a) vector data from the forest digital map of the Forest District Żołędowo: communication layer, tourist attractions and facilities, legal forms of nature protection, forest district border;
b) roads from the OpenStreetMap (OSM) project in shapefile format;
c) a digital elevation model (DEM) in raster format with resolution approximately 15 m taken from ASTER stereo image autocorrelation (Tarekegna et al. 2010);
d) vector data from the State Register of Geographical Names;
e) vector layers from the General Geographic Database: forest land cover, urban areas, water bodies, railways.

The first stage of the work was to build routable data. For this purpose it was decided to merge OpenStreetMap data with road network on the digital map of forest areas managed by the State Forests. All errors were eliminated by building and cleaning network topology function performed by means of Quantum GIS open software and GRASS geoprocessing tools (QGIS plugin).

According to Article 29. 1. of Poland's Act on Forests (1991), traffic comprising motor or animal-drawn vehicles shall only be permitted in forests on public roads. Communication layer from the forest digital map does not have any attributes related to road accessibility. This kind of information is very important for routing service, because some roads may be also excluded from public traffic due to for e.g. poor technical conditions or the presence of protected areas. Therefore, all the network lines were harmonized and classified taking into account the above aspects.

The digital elevation model in raster format was loaded to the database and then used for length and slope calculation in 3D. The slope of road segments was calculated by dividing the elevation difference by the Cartesian distance between points multiplied by 100%.

$$\alpha = \frac{h_e - h_s}{d} \cdot 100\%$$

where:

α – slope,
h_e, h_s – height of end and start points,
d – Cartesian distance between points.

Travel time in a both directions of road was calculated by dividing the distance by average speed of traffic. In the proposed system, there were considered three types of transportation means: motorcar, bicycle and travel on foot. For each road segment there was calculated travel time for each type of transportation, taking into account the road category and the value of slope:

$$t = \frac{D_s}{v \cdot f_{slope}}$$

where:

t – travel time,
D_s – distance in 3D,
v – average speed,
f_{slope} – slope factor.

The default routing application presented in this study included two types of path search: the shortest and the fastest. In the shortest path, cost search was defined as distance, whereas in the fastest – as travel time. For the purpose of the study there was implemented a custom type of route search – called natural path. This type of search took into account the location of

roads related to forest areas as well as the road category. Attribute "forest" was added to determine whether the edge of road network passed through the forest area or not. The next parameter considered was a natural factor which referred to the category of road and its surface. The cost of natural path search was a function of road length and forest and natural factors:

$$naturalcost = D_s \cdot f_{natural} \cdot f_{forest}$$

where:

naturalcost – cost for natural path search,
D_s – distance in 3D,
$f_{natural}$ – natural factor,
f_{forest} – forest factor, when road passes through forest equal 0,5, otherwise 1.

Road categories were assessed for suitability for natural route search. Rough roads, often with unpaved surfaces or roads with inferior technical conditions were preferred. The categories of roads associated with housing (residential) or urban areas (service, living street, pedestrian, steps) were considered as indifferent for the analysis.

The implementation of final data and web presentation were realized by free and open source software. The system designed utilizes PostgreSQL (URL 1) object-relational database system with PostGIS (URL 2) and pgRouting (URL 3) extensions to store and process spatial data. PostGIS adds support for geographic objects to the PostgreSQL database, allowing for the use as a spatial database for geographic information systems. PgRouting is an extendible library that provides geospatial routing functionality. Such a database is used as a data source to GeoServer services (URL 4). GeoServer is designed for interoperability and publishes data from any major spatial data source using open standards. It can create maps in a variety of output formats. GeoServer is implementation reference for OGC Web Feature Service (WFS) and Web Coverage Service (WCS) standards, as well as it constitutes a high performance certified compliant product for Web Map Service (WMS). User interface of browser-based web application is developed by means of the GeoExt framework (URL 5). GeoExt combines the web mapping library OpenLayers (URL 6) with the user interface of Ext JS (URL 7) to help build powerful desktop style GIS applications on the web with JavaScript.

Results

The front end of the service proposed is the browser-based web mapping application. The application allows collecting input from the user and is responsible for processing the data obtained. The result of data processing is exposed through a web server with PHP scripts.

The main component of the application is the interactive map and journey planner window which contains the tools needed for route planning (fig. 2). First, the user has to select the type of transportation means (this option determines journey speed and road accessibility for routing). Next step is to indicate the start and the end point of the journey. The user has got two options to mark desired locations on the map: the selection of the appropriate tool for insertion points on the map or the selection of point of interest (POI) marker for navigating around the map. After selecting the starting point, the tool for determination of the service area is available. There are two factors concerning the service area: time and distance. The user decides which factor is limiting, and then can specify factor value and perform calculation.

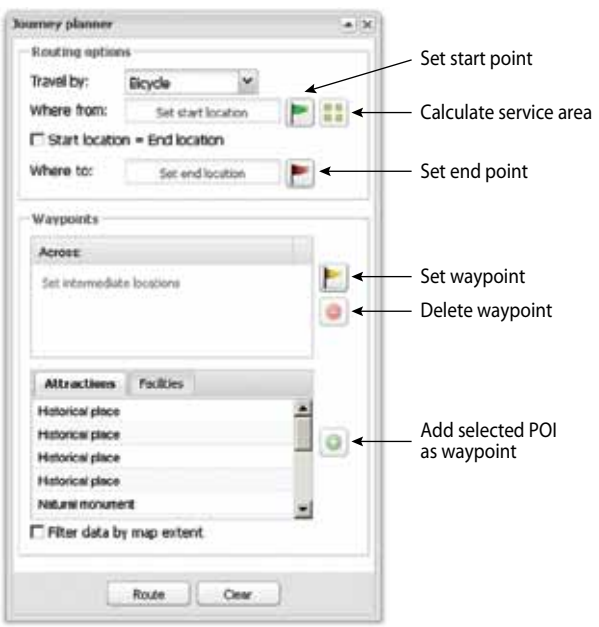

Figure 2. Journey planner window

There are three types of routes to choose: the shortest, fastest and natural (fig. 3). They are shown in a separate window with information about distance

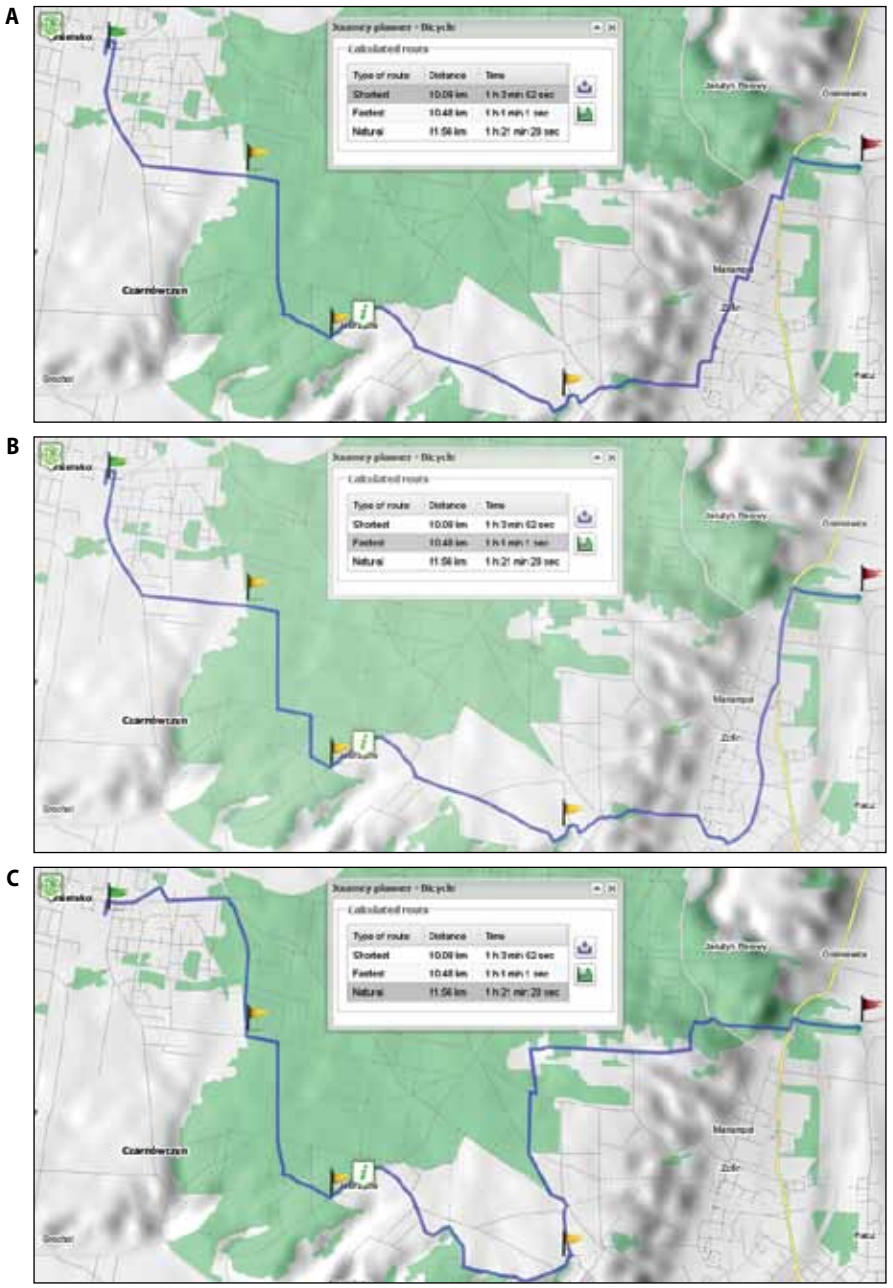

Figure 3. Routing results of different path search for bicycle ride: shortest (A), fastest (B), natural (C)

and travel time. The user can change the selection to display the route. This allows the comparison of the routes. The map prepared by the user can be saved as PDF file. The application has the feature for exporting the route planned as geospatial data in different file format and projection. Such a file can be used in navigation devices. Average speed of transportation depends on the road category and the type of transport. The fastest route prefers good quality roads whereas the nature route passes through forested areas. Designed application provides for an ability to determine waypoints to be visited during the trip.

Web mapping application utilizes a shaded relief map as a base layer. The user has an opportunity to dis-

play exact values of the elevation model along the path selected. Additionally, the user gets information on elevation gain and loss (fig. 4).

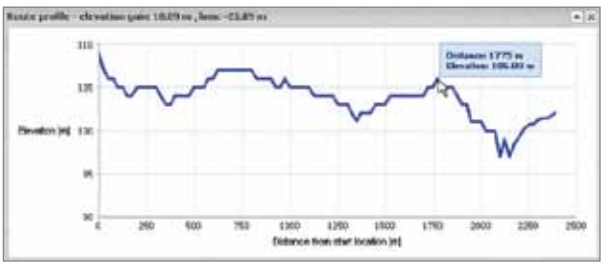

Figure 4. Route profile example

Discussion

The objective of this study was to design and create a fully functioning system for presenting in the Internet spatial data of importance for tourists, and all at once – to enable planning tourist routes in public forests. The forest digital map was used as a primary source of routing data on the forest areas. Communication layer required geoprocessing to ensure correctness of topology for network analysis. There were no attributes related to road accessibility on the map used in the study, both in terms of technical quality and traffic permission. Supplementing these elements was extremely important for the routing application elaborated because these were needed for route planning no more than within allowed areas. In other words, these attributes were used to drive traffic avoiding the areas not accessible to the public.

The proposed system was built on well-known and powerful open source geospatial components. New functions were designed and programmed. The calculations considered three types of transportation means (by motorcar, bicycle and by foot) and different categories of roads. There were implemented three types of path search: the shortest, the fastest and a custom type called – natural. The search took into account the location of roads related to forest areas and the type of road. The digital elevation model was used to calculate the length of roads and to model the impact of slope on travel time, depending on the direction of movement.

The geoportal created provides compact information on tourist attractions in the area managed by the Forest District Żołędowo and gives a possibility to plan routes that meet pre-specified criteria. Moreover, it helps to arrange balanced tourism only there where it is legal and safe for natural resources. Designed system is a universal model and can be implemented in any other forest district. Appropriate preparing and geoprocessing of communication layer from the forest digital map is the only condition to successfully found the application. Development of routing systems for the areas managed by state foresters can be improved by taking into consideration network data requirements during forest management planning. In particular, it is important to ensure topological quality of network data and to complement the attributes that determine accessibility of roads. In the age of the Internet, the designed application can grab great attention of people looking for a place where they can relax and take a break from busy city life. In the future, this geoportal could be adapted to requirements of mobile devices such as smartphones and palmtops. The presented way of using network analysis allows for tourist traffic management while preserving environmentally valuable areas. Attributable to the use of the proposed system there can be achieved further development of sustainable tourism and promotion of Poland's forest areas managed by the State Forests – National Forest Holding.

Conclusions

- Growing interest of tourism in forest areas should be controlled in order to protect valuable forest ecosystems against gradual devastation.
- The Internet is the most common and easy to use source of tourist information, and therefore administration of forest districts could use it efficiently to direct tourist activities within their territories.
- State Forest's digital map stores line vector data which can be easy implemented in GIS network representations – the best solution to create tourist geoportals.
- Taking into account economic conditions, it is advisable to use free open source software to create sophisticated user interface and routing engine which can be easily modified.
- This paper presents ready to use software which may be implemented in every forest district any time.

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URL 2: PostGIS; http://postgis.refractions.net

URL 3: pgRouting; http://www.pgrouting.org

URL 4: Geoserver; http://geoserver.org

URL 5: GeoExt; http://geoext.org

URL 6: OpenLayers; http://openlayers.org

URL 7: Ext JS; http://www.sencha.com/products/extjs3